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(54) Beam column for charged particle device

(57) A charged particle beam column with a first vacuum chamber further comprises a particle source for providing a beam of charged particles and a multi aperture unit with at least two beam defining apertures for shaping the beam of charged particles. The particle source and the beam defining apertures are located within the first vacuum chamber. A separation unit for isolating a second vacuum chamber from the first vacuum chamber whereby the separation unit comprises a path aperture for the charged particle beam is arranged between the first and second vacuum chamber. A first deflecting unit directs the beam of charged particles through one of the beam defining apertures and a second deflecting unit directs the beam of charged particles through the path aperture.

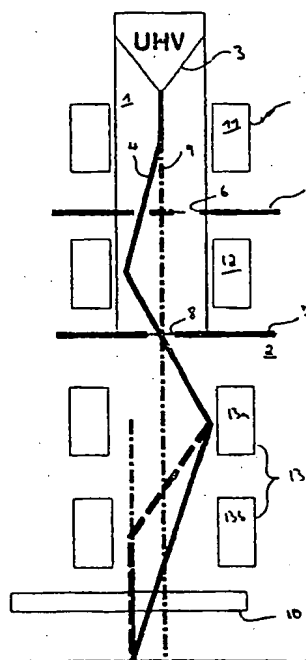


Fig. 1

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Description

FIELD OF THE INVENTION

[0001] This invention relates to a charged particle beam device for the examination of specimen. In particular, this invention relates to the beam column used for guiding the charged particle beam.

BACKGROUND OF THE INVENTION

[0002] Beams of negatively or positively charged particles can be used for the examination of specimen. Compared to optical light, the resolving power of a beam of charged particles is several magnitudes higher and allows for the examination of much finer details. In charged particle beam devices, electric or magnetic fields, or a combination thereof, act upon the beam in a manner analogous to that in which an optical lens acts upon a light beam. In particular, any electric or magnetic field which is symmetrical about an axis is capable of forming either a real or a virtual charged particle image. Hence, an axially symmetric electric or magnetic field is analogous to a spherical lens. Furthermore, similar to light-optics, apertures are also used in charged particle devices. The primary use of these apertures is to limit the diameter of the beam of charged particles or to eliminate stray or widely scattered particles. However, in charged particle devices, apertures are an easy target for contamination caused by hydrogen carbons.

[0003] Charged particles on their path from particle source to the specimen to be examined are strongly scattered by all forms of matter including air. Hence, the entire instrument must, in general, be evacuated. Nevertheless, the presence of hydrocarbon molecules in vacuum chambers is virtually unavoidable. These are commonly formed in vacuum chambers of the charged particle devices as a result of hydrocarbons and silicon oils migrating from vacuum pumps or evaporated from vacuum seals. Radiation of hydrocarbon molecules with charged particles leads to cracking of bonds and to the creation of carbon double bonds. The formation of carbon double bonds, in turn, results in cross linking and the final product will be a carbonaceous polymerized substance. In particular, the edges of apertures which serve to limit the diameter of a particle beam are exposed to particle radiation. At these edges, carbon-rich films or contamination needles easily form and grow into the openings which changes the shape of the passing beam.

[0004] Furthermore, these contaminations protruding into the openings are getting charged by the particle beam. The impinging particles are absorbed by the protrusions which could primarily be classified as insulators. The charge build up causes the passing particle beam to deflect and results in imaging artifacts. Due to the constant accumulation of charge, the voltage of a contamination increases until it reaches the break down

point. In this moment, a sudden discharge will take place and the imaging artifact, caused by charging, disappears. The subsequent absorption of charged particles will again build up the voltage of the contamination until it reaches the break down point. Consequently, this results in a periodical artifact of image flickering. Additionally, there is the artifact caused by the slowly growing contamination layer at the edge of an aperture which steadily narrows the diameter of the passing beam.

[0005] In some devices multi apertures have been used for obtaining a variety of preselected beam diameters. A plate comprising several apertures with distinct diameters is placed between particle source and specimen. The beam of charged particles is then guided through one of these apertures in order to reduce it to a desired diameter before it impinges onto the specimen to be examined. Without limiting the scope of the invention, the following explanations will primarily concentrate on the use of electrons as charged particles. An impinging beam of electrons with a given electron density and a bigger beam diameter causes more primary electrons to hit the target. The higher number of interactions between primary electrons and target result, in general, in an increase of secondary products being detected and, consequently, in a higher imaging contrast. On the other hand, a smaller beam diameter with fewer primary electrons getting absorbed by the target causes lesser charging and allows for focusing the beam to a smaller diameter in the sample plane.

[0006] In particular small apertures of multi aperture units require frequent cleaning due to high intensity radiation of their edges. Furthermore, frequent cleaning is necessary because of the large influence a contamination spot of given size has with respect to the total surface of a small apertures. For cleaning, the part of the electron beam column containing the multi aperture unit needs to be opened and its vacuum broken. After cleaning, time consuming realignment and adjustment steps are necessary before the electron beam device is fully operational again. Since this procedure results in considerable machine down-time, it is desirable to increase the interval at which such apertures need to be cleaned.

[0007] In the past, a variety of attempts have been made to reduce contamination of apertures e.g. use of hydrocarbon free vacuum and appropriate prior cleaning of vacuum chamber and aperture unit. In another attempt, apertures were heated during machine running time. The increased Brownian movement of the molecules at the edges of the apertures prevent the formation of contamination layers thereon. Yet, the installation of heaters in the vicinity of apertures is burdensome and costly.

SUMMARY OF THE INVENTION

[0008] The present invention intends to provide an improved charged beam column for examining a speci-

[0009] According to a further aspect, the present invention also provides a method as specified in claim 11.

[0011] According to preferred aspect there is provided a charged particle beam column with a first vacuum chamber. The charged particle beam device further comprises a particle source for providing a beam of charged particles and a multi aperture unit with at least two beam defining apertures for shaping the beam of charged particles. The particle source and the beam defining apertures are located within the first vacuum chamber. A separation unit for isolating a second vacuum chamber from the first vacuum chamber whereby the separation unit comprises a path aperture for the charged particle beam is arranged between the first and second vacuum chamber. A first deflecting unit directs the beam of charged particles through one of the beam defining apertures and a second deflecting unit directs the beam of charged particles through the path aperture.

[0013] In a further preferred aspect of the present invention, the second deflecting unit guiding the beam of charged particles through the pass aperture comprises two stages. The first one guides the beam coming through a selected beam defining apertures back to the optical axis. Then, the second stage guides it along the optical axis or, alternatively, in close vicinity to the optical axis. Advantageously, this allows the beam to be directed onto a trajectory close to the optical axis even before it passes through the path aperture of the separation unit. The second deflection unit already guides the beam to a direction so that it propagates towards the target or specimen without having to be directed again by a third deflecting unit.

rects the charged particle beam so that the angle between the optical axis and the beam is reduced. Preferably, the third deflection unit is located in between separation unit and specimen.

[0016] In another preferred embodiment, the vacuum in the first vacuum chamber is higher than the vacuum in the second chamber. Advantageously, the multi aperture located in the first vacuum chamber is kept at a higher vacuum. Thus, the time span in which contaminants develop at the path aperture and start to negatively influence the trajectory of the charged particle beam is slowed down by specifically reducing the number of hydrocarbons in this area. At the same time it is not necessary to maintain the vacuum level of the first vacuum chamber in parts of the beam column where contaminants have lesser disturbing influence.

[0018] The invention is also directed to methods by which the described apparatus operates. It includes method steps for carrying out every function of the apparatus. These method steps may be performed by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner.

[0019] Some of the above indicated and other more detailed aspects of the invention will be described in the following description and partially illustrated with reference to the figures. Therein:

Fig. 2 is a schematic vertical cross section of a sec-

ond embodiment of a beam column for a charged particle beam device comprising a first, a second and a third double stage deflection unit. The first and second deflection unit are arranged within a first vacuum chamber.

Fig. 3 is a schematic vertical cross section of a third embodiment of a beam column for a charged particle beam device comprising a first and a second double stage deflection unit. The first and second deflection unit are arranged within the first vacuum chamber.

Fig. 4 is a schematic vertical cross section of a fourth embodiment of a beam column for a charged particle beam device comprising a first, a second and a third double stage deflection unit. The first and second deflection unit are arranged within the first vacuum chamber

Fig. 5 shows a top view of a multi aperture unit with several beam defining apertures arranged in a circle around the center beam defining aperture located in the middle of the circular plate.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] An exemplary embodiment of an electron beam column used in an apparatus for examining specimen is shown in Fig. 1. Electron beam 4 comes from electron source 3 e.g. a Schottky emitter or a tungsten hairpin. An anode arranged below attracts and accelerates the electrons and a condenser lens concentrates them into a fine beam. Both, anode and condenser lens, are not shown in the drawings since they are not crucial for understanding the principals of the invention. A first deflection unit 11 deflects the e-beam path from optical axis 9 defined by electron source 3 and guides the e-beam through one of the beam defining openings 6 in multi aperture 5.

[0021] In the embodiment shown, multi aperture 5 is a circular flat disc having several beam defining openings 6 with a specified diameter. Before the e-beam passes through one of these openings, it generally has a diameter bigger than the diameter of the opening. Thus, the beam defining aperture only allows electrons to pass who's distance from the e-beam axis is smaller than the aperture diameter and eliminates the rest. The first deflection unit is capable of directing e-beam 4 through any one of the beam defining apertures 6 in multi aperture unit 5 thereby determining the beam diameter and, consequently, the current of the e-beam. The selection of a specific beam defining aperture is the choice of the user and based on his intentions. In view of the present invention, it is not required to arrange beam defining apertures 6 in a specific pattern on multi aperture unit 5. It is, however, preferred to have suffi-

cient distance between outer rims of adjacent apertures so tat electrons flying on the outmost trajectories of the e-beam do not incidentally pass through neighboring apertures. On the other hand, the distances between outer rims of adjacent apertures should not be too wide. This permits deflections of the e-beam wit smaller angles since the center of beam defining apertures 6 are arranged closer to the center of multi aperture unit 5. Furthermore, it is preferred to have one beam defining aperture located in the center of multi aperture unit 5. If a certain application requires the use of the center aperture, then it is not necessary to deflect the e-beam which can remain on the optical axis.

[0022] A second deflection unit 12 redirects the beam after its diameter has been defined by one of apertures 6 and guides it trough pat aperture 8 of separation unit 7. The separation unit 7 is located between a first vacuum chamber 1 and a second vacuum chamber 2 and separates the two vacuums existing in each respective chamber. Thereby, the vacuum in the first chamber 1 is higher than the vacuum in the second chamber 2 or, in other words, the pressure in the second chamber is higher than the pressure in the first chamber. This reduces the number of hydrocarbon molecules in the surroundings of the beam defining apertures thus slowing down the formation of contaminants. In preferred embodiments, the vacuum in the first chamber 1 is at least five times as high as the vacuum in the second chamber. In even more preferred embodiments, the vacuum in the first chamber is at least 10 times as high as the vacuum in the second chamber. By establishing a pressure difference of about one magnitude, the number of hydrocarbon molecules present in the first chamber, compared with the number of hydrocarbon molecules present in the subsequent second chamber, is considerably reduced which results in even more enhanced running times of the charged particle-beam device.

[0023] Alternatively, it is preferred to establish in the first vacuum chamber 1 an ultra high vacuum of higher than 10^{-7} mbar. This reduces the number of all molecules including hydrocarbon molecules per cm^{-3} to not more than 10^9 and, consequently, slows down the formation of contamination spots. In even more preferred embodiments, an additional high vacuum of about 10^{-4} mbar to about 10^{-7} mbar is established in vacuum chamber 2. The additional existence of a high vacuum in the second vacuum chamber adjacent to the first vacuum chamber enhances machine running time even more. It is of course possible and advantageous to combine the aspects of establishing vacuum gradients as described in the preceding paragraph with the aspects of establishing an ultra high vacuum in the first vacuum chamber as described in the present paragraph.

[0024] Beam defining apertures 6 of multi aperture unit 5 are all arranged in vacuum chamber 1 which, preferably, also includes electron source 3. It is within the scope of the invention to place multi aperture plate

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[0032] Fig. 2 shows a further embodiment according to the invention. Different to the above described beam column, the first and second deflection unit are now located within first vacuum chamber 1. The smaller distance between deflection units and e-beam to be deflected allows the use of deflection units operating with weaker electromagnetic fields. Furthermore, a much larger variety of materials may be used for producing the walls of vacuum chamber 1 since their influence on the deflection fields are considerably smaller.

[0033] An alternative arrangement of deflection units is shown in fig. 3. Here, second deflection unit 12 comprises two deflection stages 12a and 12b. This embodiment is preferably used in beam columns in which the optical axis defined by path aperture 8 and the optical axis defined by objective lens 10 are coaxial. The e-beam, after having been delimited by beam defining aperture 6, diverges from optical axis 9. In a first step, deflection unit 12a redirects e-beam and guides it back towards the optical axis. At the point of intersection or, in case the e-beam does not intersect with optical axis 9, at a point where the e-beam passes optical axis 9 in close vicinity, deflection unit 12b redirects e-beam so that it propagates along optical axis 9 or in close vicinity to optical axis 9 and more or less parallel to it. The expression "more or less parallel" within the meaning of this invention includes deviations in which the e-beam still passes the objective lens close to its center without causing excessive imaging artifacts.

[0034] The provision of a double stage second deflection unit 12a and 12b disposes, in certain applications, the provision of a third deflection stage 13, since e-beam 4 already propagates in a direction close to the optical axis. Nevertheless, even in a beam column with a double stage second deflection unit 12a and 12b, it is in some applications preferred to have an additional double stage third deflection unit 13a and 13b. The provision of such allows, after the beam has passed path aperture 8, conducting a parallel shift of the e-beam.

[0035] Fig. 4 shows a still further embodiment according to the invention. Here, a single stage second deflection unit 12 is combined with a double stage third deflection unit 13. Such an arrangement is advantageously used in beam columns in which the optical axes defined by path aperture 8 and objective lens 10 are coaxial. Compared with the arrangement shown in fig. 3, an additional deflection stage has to be used. On the other hand, the part of the beam column between separation unit 7 and objective lens 10 is in many devices more spacious than the upper part of the beam column and allows more options in installing the third deflection units. It is within the scope of the present invention to arrange the first and second deflection units, as shown in figs. 3 and 4, outside vacuum chamber 1 as well.

[0036] Fig. 5 shows a top view of a multi aperture unit with several beam defining apertures arranged in a circle around a center beam defining aperture which is located in the middle of the circular plate. It is possible

to use a multi aperture blade with a larger diameter without changing the arrangement of beam defining apertures 6 in respect to each other and without changing their dimensions. This increases the outer rim of multi aperture plate 5 and adapts it to various sizes of vacuum chambers. With a distance of about 5 cm between charged particle source and multi aperture plate and aperture sizes between 5 μ m and 50 μ m the beam current can be varied by a factor of 100.

[0037] Fig. 6 shows the embodiment of fig. 3 including one modification. Separation unit 7 comprises a further separation means 7a which is also provided with a path aperture 8a. The space created between the two plates can function as independent vacuum chamber 14 connected to an own vacuum pump (not shown). The installment of an additional vacuum chamber 14 allows better isolation between the first and second vacuum chamber. Gas molecules moving from the higher pressure second vacuum chamber 2 through path aperture 8a in direction of lower pressure vacuum chamber 1 get trapped in isolation vacuum chamber 14. Caught in this chamber, these molecules can be evacuated before they enter the first vacuum chamber. Hence, it is easier to maintain a desired vacuum gradient between the first and second vacuum chamber. The double path aperture described above can be used in all other embodiments according to the present invention, in particular in those shown in figs. 1, 2 and 4.

[0038] The double path aperture, compared with a single path aperture, still provides better isolation even so it is not connected to a vacuum pump. In this case the space between the two plates does not function as a vacuum chamber, however, gas particles still need to pass both apertures before they can contribute to the pressure in the adjacent chamber. This preferred embodiment does not require an additional vacuum chamber.

Claims

1. A charged particle beam column comprising:

- a first vacuum chamber (1);
- a particle source (3) for providing a beam of charged particles (4) propagating along an optical axis (9);
- a multi aperture unit (5) comprising at least two beam defining apertures (6) for shaping the beam of charged particles, the particle source and the beam defining apertures being located within the first vacuum chamber;
- a separation unit (7) for isolating a second vacuum chamber (2) from the first vacuum chamber whereby the separation unit comprises a path aperture (8) for the charged particle beam;
- a first deflecting unit (11) for directing the beam of charged particles through one of the beam

defining apertures (6); and
a second deflecting unit (12) for directing the beam of charged particles through the path aperture (8).

2. The charged particle beam column according to claim 1 wherein the first and/or the second deflecting unit (11, 12) is located outside the first vacuum chamber. 5
3. The charged particle beam column according to any of the preceding claims whereby the second deflecting unit (12) comprises two deflecting stages, a first stage (12a) for directing the beam of charged particles towards the optical axis (9) and a second stage (12b) for directing the beam of charged particles onto or in close vicinity to the optical axis (9). 10 15
4. The charged particle beam column according to any of the preceding claims further comprising a third deflecting unit (13) for directing the beam of charged particles through an objective lens (10). 20
5. The charged particle beam column according to claim 4 whereby the third deflecting unit (13) is located downstream the separation unit (7). 25
6. The charged particle beam column according to claims 4 or 5 whereby the third deflecting unit (13) comprises two deflecting stages, a first stage (13a) for directing the beam of charged particles towards the optical axis (9) and a second stage (13b) for directing the beam of charged particles onto or in close vicinity to the optical axis (9). 30 35
7. The charged particle beam column according to any of the preceding claims whereby the diameter of the path aperture (8) is larger than the largest diameter of the beam defining apertures (6). 40
8. The charged particle beam column according to any of the preceding claims whereby the vacuum established in the first chamber 1 is higher than the vacuum established in the second chamber 2, preferably the vacuum in the first vacuum chamber is 5 times higher than the vacuum in the second vacuum chamber, more preferably the vacuum in the first vacuum chamber is 10 times higher than the vacuum in the second vacuum chamber. 45 50
9. The charged particle beam column according to any of the preceding claims whereby the first vacuum chamber is an ultra high vacuum chamber. 55
10. The charged particle beam column according to any of the preceding claims whereby the second vacuum chamber is a high vacuum chamber.

11. A method of guiding a charged particle beam through a charged particle beam column comprising the following steps:

- a. using a first deflection unit to guide a charged particle beam through a beam defining aperture of a multi aperture unit located in a first vacuum chamber;
- b. using a second deflection unit to guide the charged particle beam through a path aperture of a separation unit isolating the first vacuum chamber from a second vacuum chamber.

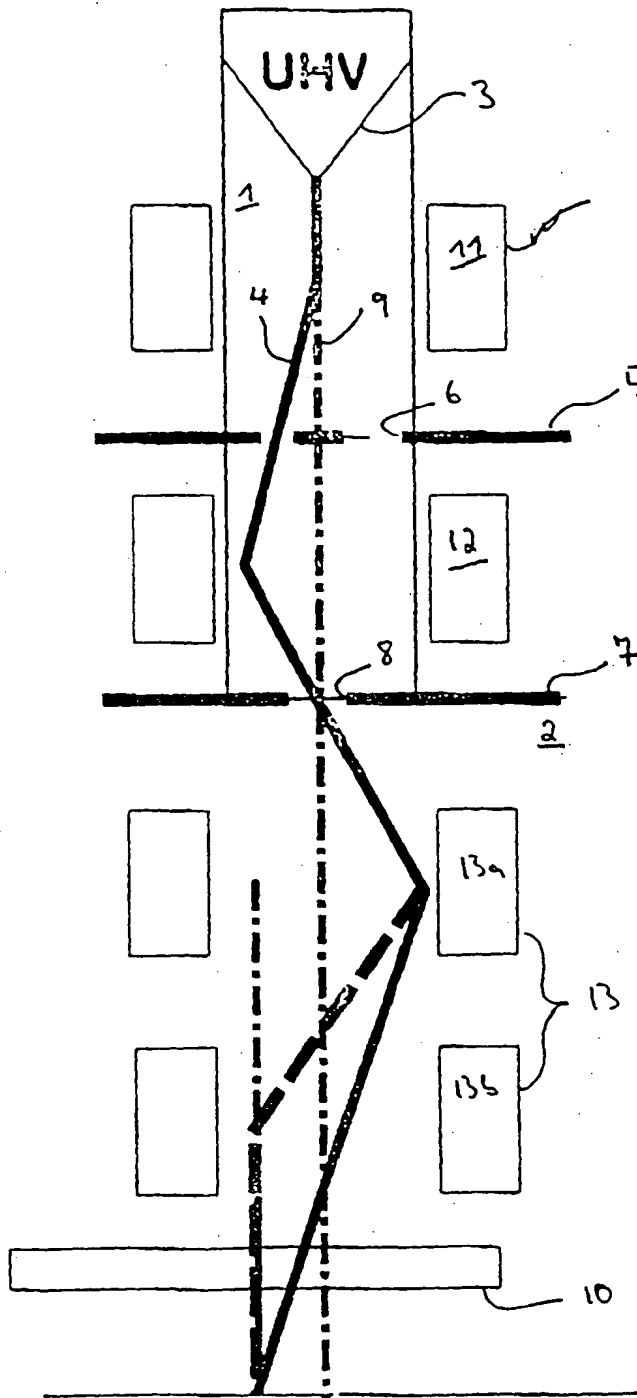


Fig. 1

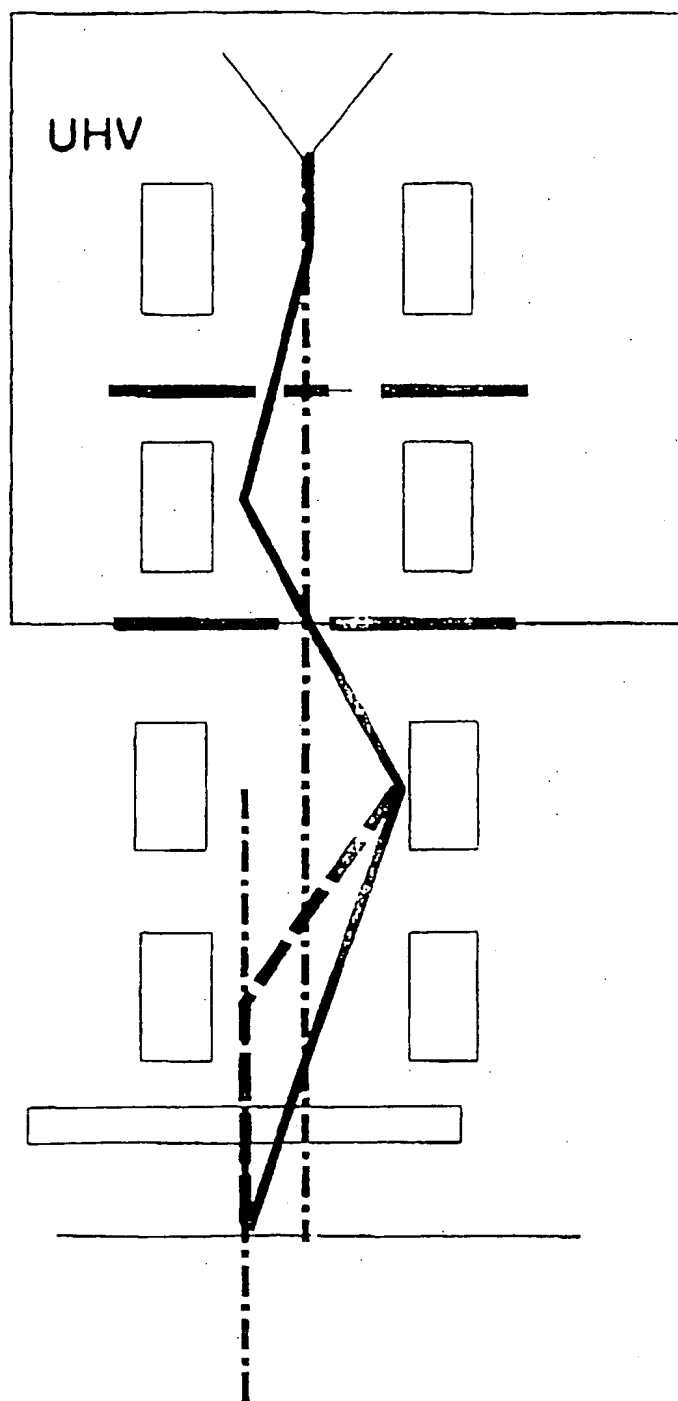


Fig-2

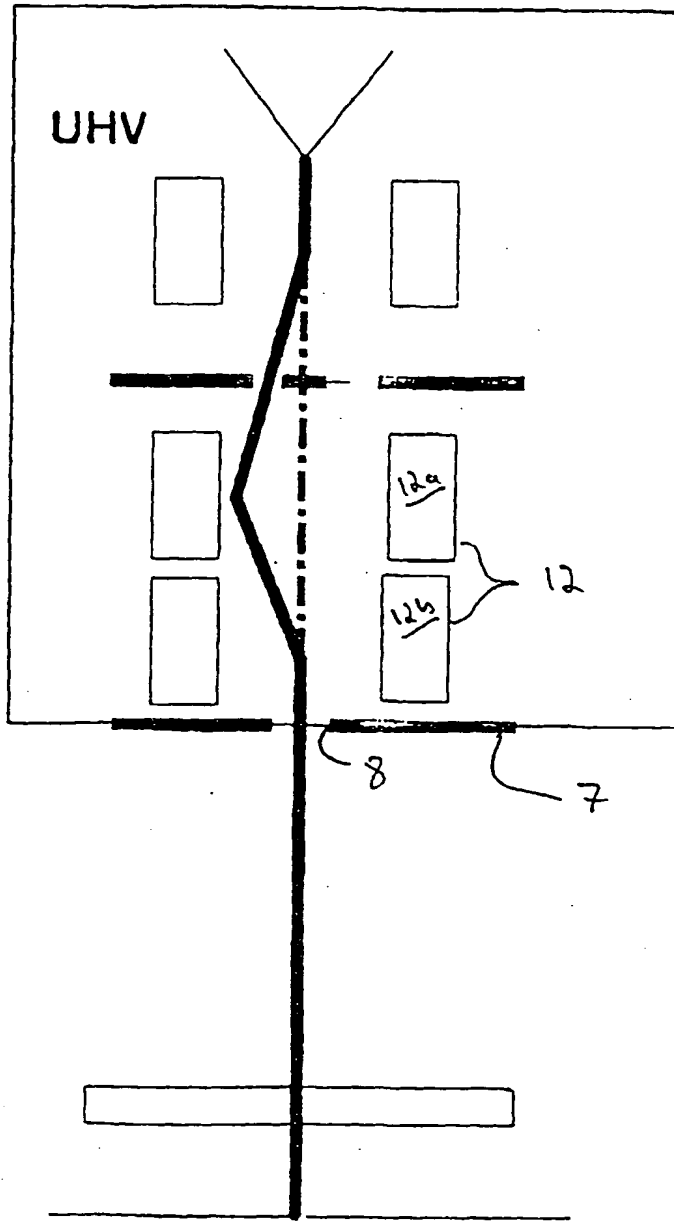


Fig. 3

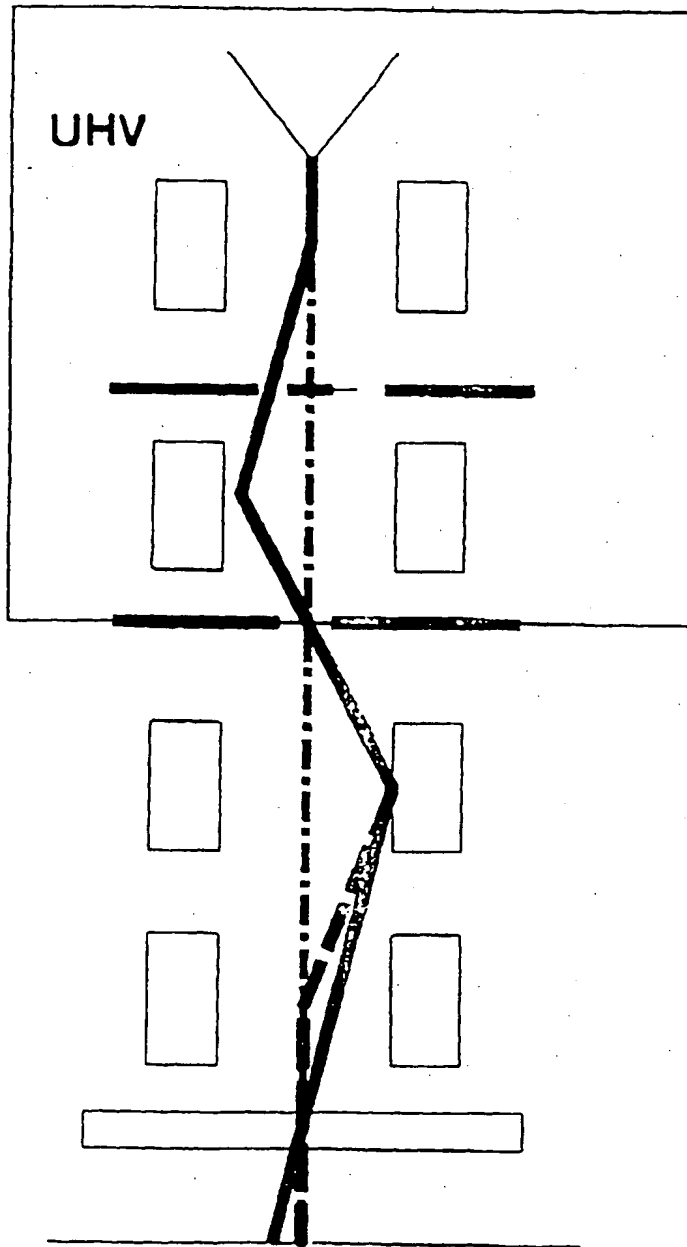


Fig. 4

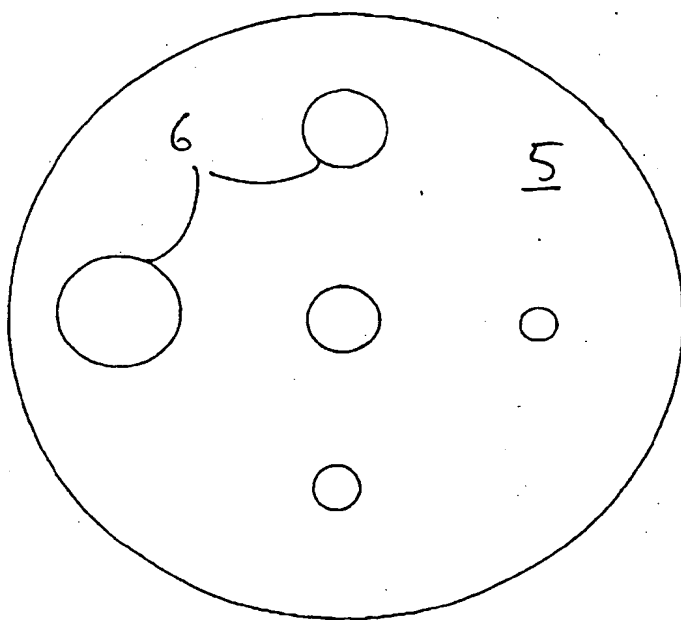


Fig. 5

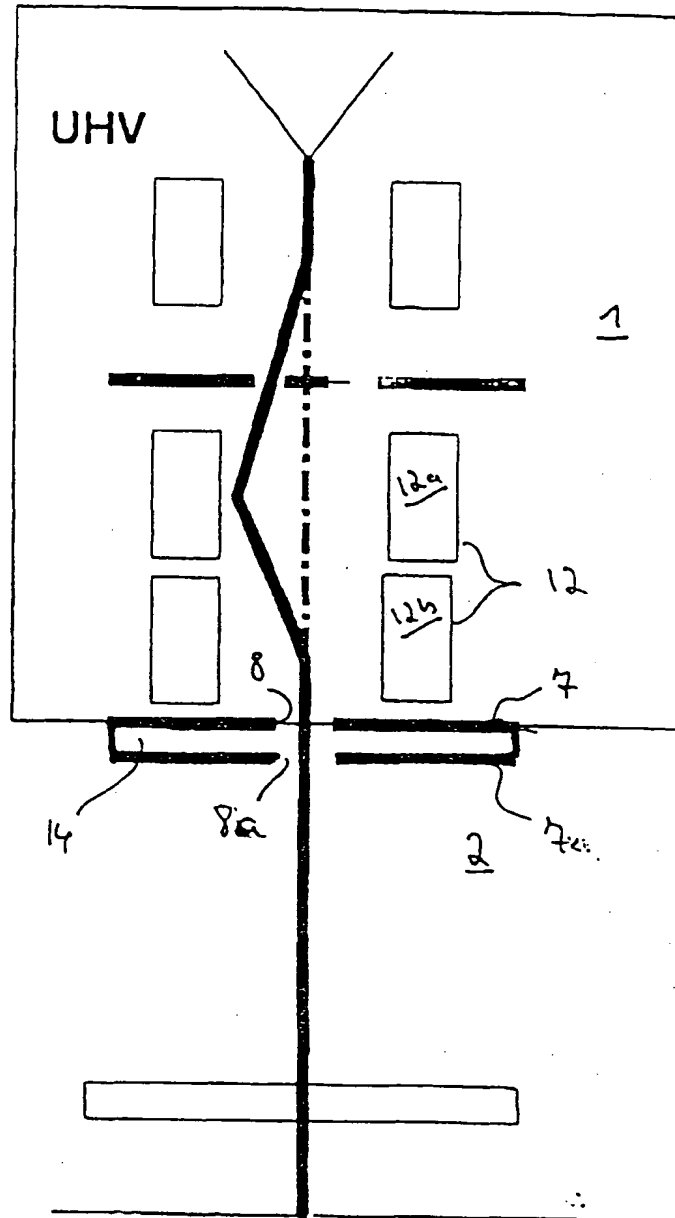


Fig. 6



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 98 12 1201

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 797 236 A (FUJITSU LTD; ADVANTEST CORP (JP)) 24 September 1997	11	H01J37/301 H01J37/147
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A	US 4 651 003 A (FEUERBAUM HANS-PETER) 17 March 1987 * column 4, line 4 - column 4, line 32 * * column 5, line 12 - column 5, line 14; figures 1,2 *	1-11	
A	US 5 466 942 A (SAKAI ITSUKO ET AL) 14 November 1995 * column 5, line 43-57; figure 3 *	1-11	
A	EP 0 179 294 A (HITACHI LTD) 30 April 1986 * column 2, line 40 - column 3, line 34; figures 1,3 *	1-11	
A	FR 2 488 043 A (LE N PROIZV) 5 February 1982 * page 5, line 9 - page 5, line 35; figure 3 *	1-11	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01J
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 10 May 1999	Examiner Zuccatti, S
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 98 12 1201

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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